COAL what's the alternative?

Traditional coal could be difficult to source or become too expensive if the Department for Environment, Food and Rural Affairs enforces its coal ban. **THOMAS BRIGHT** explores the alternatives to 'black gold'.

For footplatemen of all generations, the rumble of coal tumbling down from the bunker or tender onto the fireman's shovel, and the accompanying 'schwing' as the round flies off the blade and into the firebox, is perhaps the most evocative of all railway noises. But that sound, so characteristic of steam railways, is under serious threat.

In the last two editions of *Steam Railway* we have explained how our supply of coal is at risk from proposals put forward by the Department for Environment, Food & Rural Affairs to ban the sale of traditional house coal, which could have grave consequences for the whole steam preservation community.

The potential outcome is that we will be totally reliant on imports, which could be prohibitively expensive, and that the screening and distribution network critical for supplying sized, lumped coal could disappear if the demand from the household market is extinguished.

Faced with such a threat, would it be worth preservation's while to abandon coal altogether and invest in alternative fuels? Are these fuels viable, and what are their respective pros and cons?

Surely oil firing is the most obvious solution?

On paper, yes. Many railways converted a number of their locomotives to oil firing in steam days, and both the Ffestiniog and Vale of Rheidol railways have been extensive operators of oil-fired engines in more recent years. Furthermore, oil has a similar energy density to coal (more on that later).

Given that oil firing has a historical precedent, and that it has proven its viability on both standard and narrow gauge locomotives, could we – or should we – explore this as an alternative to coal?

The Ffestiniog Railway decided to switch to oil firing in the early 1970s as a way of reducing spark throwing from "little engines running through the woods and working hard," says Boston Lodge Chief Mechanical Engineer Jon Whalley. At the time, the railway was paying £2,000 a year (nearly £26,000 in today's money) for fire patrols to extinguish lineside fires, so converting the fleet to oil firing was deemed a necessity.

Ex-Penrhyn Quarry Railway Hunslet 2-4-0STT *Linda* was the first of the FR fleet to be converted, in autumn 1970. After much fine-tuning, the oil-burning equipment was shown to be effective and present an advantage over traditional coal burning. Writing in the April 1972 edition of *The Railway Magazine*, the FR's then general manager, Allan Garraway, explained: "Oil burning plus

The fireman at work on 'S15' No. 847 at the Bluebell Railway on February 24. This timeless scene could be irrevocably changed if DEFRA enforces a ban on the sale of traditional house coal. CLIVE HANLEY

superheating looks like giving a substantial saving in fuel costs, but it also gives other savings and advantages.

"There is no coal to unload and handle; fuel oil is pumped direct from road or rail tanker and involves one man for a few minutes per delivery. It takes a fireman only a few minutes of pumping – less still when it's fully mechanised.

"There are no fires or ashpans to clean, and engines can turn around at terminals in the time it takes to get water. Tubes are cleaned by sand each trip, but otherwise smokeboxes and tubes are never touched. No ashes and dirt soil the carriages, and overalls are kept far cleaner.

"From the fireman's standpoint, it has taken away most of the dirt and hard work, but it is not the simple, boring task many anticipate. The fireman has to know the road and his driver, and adjust his burner controls to every little change in steam consumption. Yet, if an inexperienced fireman lets things drop back, it is much easier for the driver to tell him how to put it right, as oil burning gives more or less instant results.

"Steam-raising is easy; plug in the air line to the manifold, turn on the oil, atomising air and blower, and light the burner. An engine can be in steam very quickly, and this can be very useful.

"It is possible to have full steaming rates as quickly as the engine requires (or as hard as the blower will allow) and the flame is uniform right around the whole firebox; the firedoor is never opened – admitting draughts of cold air straight onto the tubes – and there is no mechanical wear on fire irons and shovels, nor corrosion from wet ashes in the smokebox."

Oil firing was deemed to have so many advantages over coal that the majority of the FR fleet was converted, with the railway fielding the largest fleet of oil-fired locomotives in the country. Furthermore, although oil firing is perceived to emit great columns of black smoke: "When you burn a lighter oil – provided the locomotive is in good order – you can run with a very clean exhaust," says Jon.

SNAKE OIL

Oil firing sounds great. However, there's a 'but'…

There's a good reason why the FR converted its fleet back to coal around the turn of the decade, a status quo echoed at Aberystwyth, where the Vale of Rheidol Railway has outshopped freshly overhauled 2-6-2T No. 7 as a coal burner, bringing it in line with the other VoR locomotives which were similarly retro-converted.

"Oil firing costs twice as much in fuel as coal, perhaps more, and I don't think the respective prices have changed. I don't think we'd want to go back to oil firing any time soon, even if coal prices rise – I think we'd rather refine our coal-firing techniques instead," says Jon.

Ffestiniog & Welsh Highland Railways General Manager Paul Lewin estimates that Welsh steam coal currently costs £185 per tonne, while the equivalent amount of oil costs £660, something that no railway can afford without significantly damaging its business (see News).

Even taking costs out of the equation, oil firing still isn't viable. Firstly, it is damaging to copper fireboxes – with which the vast majority of our national locomotive fleet is fitted – and, while it worked with some success on the FR and VoR, there are doubts as to its suitability in larger fireboxes on standard gauge engines. Secondly, Paul says: "No one has invested in oil firing technology, so the current systems are very old and inefficient."

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> JON WHALLEY, CHIEF MECHANICAL ENGINEER, BOSTON LODGE

Double Fairlie *David Lloyd George* crosses the Cob with a demonstration slate train on October 15 2011, prior to its conversion to coal firing. Note the clean exhaust, something not always associated with oil-fired locomotives. CHRIS PARRY/FFWHR

Another issue is that oil – or more specifically diesel – faces an even greater threat to its existence than coal. The Government plans to outlaw the sale of new, conventional petrol and diesel cars and vans by 2040, and in its Clean Air Strategy 2019 – the same document that outlines its proposals to ban the sale of coal for household use – DEFRA states that: "By spring 2019, the rail industry will produce recommendations and a route map to phase out diesel-only trains by 2040."

In other words, sourcing affordable oil may be just as difficult and expensive as coal – if not more so.

So, oil firing is out. Can't we just use ovoids, like BR did?

If DEFRA's proposals come to pass, the only sized, lumped 'coal' widely available could be so-called smokeless ovoids or briquettes. These are a compacted form of anthracite-based coal, designed to burn for long periods with minimal smoke. Because of their 'smokeless' properties, DEFRA wants to encourage households to switch to these 'cleaner' ovoids and phase out the sale of traditional bituminous coal.

But can we use them? British Railways introduced ovoids in the post-war years as an economy measure. They were primarily made from coal slack mixed with cement dust and other binding agents, and they were almost universally despised by crews for their poor quality. Nonetheless, they do have historical precedent and, unlike any other alternative fuels, they are coal after all, so can we overcome their shortcomings?

"No, is the very short and simple answer," says Howard Johnson, the former managing director of Johnson Wholesale Fuels Ltd and who has nearly 40 years' experience in the coal industry.

"Typical ovoids come in a range of sizes, the largest of which would easily fit within your cupped hand, so it would be far too small for use in anything other than perhaps narrow gauge or small engines. The ovoids that were available in BR days were much larger and manufactured differently, and would still be unsuitable if they were available today."

Ian Moulson, sales manager for Hargreaves – preservation's biggest coal supplier – agrees: "None of our smokeless fuel products would be technically suitable, and currently all are priced significantly higher than bituminous coal.

"However, manufacture of an ovoid for the heritage rail industry is a potential for the future if and when a coal ban is introduced, and we have decided to trial our largest smokeless ovoid with a current railway user of smaller Ffos-y-Fran coal. It will be interesting to see the results."

NULL AND OVOID

The ultimate nail in the ovoids' coffin is price. Ovoids are typically more expensive (up to £400 per tonne) than traditional steam coal, a situation that will be exacerbated if DEFRA enforces its maximum 2% sulphur content for all solid fuels, as Howard explains.

"When DEFRA implements its sulphur limits, then all the ovoids will be required to be made from low-sulphur (<2%) petroleum coke, or 'petcoke', which is approximately five times the price of the high-sulphur material. Currently, low-sulphur ovoids retail at £550-600 per tonne." So, even if ovoids were a suitable substitute for coal, they are as prohibitively expensive as oil.

If we can't use coal, are there any other solid, combustible fuels that could take its place? Although widely used elsewhere in the world – particularly in places where coal is not so freely available – wood is not a viable alternative in Britain.

The main reason behind DEFRA's plan to restrict the sale of solid fuels for household use is to reduce national particulate matter emissions, of which 38% is estimated to come from the household market. CoalImp – the Association of UK Coal Importers and Producers – estimates that wood rather than coal is the "major problem, accounting for around 34% out of a total of 38% of such emissions from this sector".

Another issue with wood is energy density and volume. Paul Lewin estimates that both coal and oil produce approximately 29 kilojoules of energy per kilogram of coal/litre of diesel, whereas a kilogram of dried timber only generates 19 kilojoules – and thus has two thirds the energy.

A tonne of coal occupies 1.1m³ (approximately 39ft³), whereas a tonne of dried wood takes up 2.1m³ (approximately 74ft³). But, as wood only has two thirds the energy of coal, you'd need 112ft³ of wood – almost three times the amount of coal – to have the same amount of energy. In other words, if you filled a tender or bunker with wood, it would only get you a third as far as the equivalent volume of coal, so wood has too many environmental and practical disadvantages to be a viable substitute for coal.

However, there is a wood-derived fuel that could be a practical substitute. What's more, it's already in use at the South Tynedale Railway in Cumbria.

In 2014, the railway was awarded a grant from the Heritage Lottery Fund which, among other environmental objectives, also funded the rebuild of 1937-built Hunslet 0-4-2T Works No. 1859 *Carlisle* – now named 'Green Dragon' – so it could burn processed natural wood fuel logs, known as 'Blazer Logs'.

These are already in use on Lake Coniston, powering the National Trust's steam yacht *Gondola* but, as STR driver and Heritage Railway Association Education Adviser Martin Ashley says: "A yacht that chuffs steadily and sedately across a lake is a very different proposition to a railway locomotive that must one minute behave itself quietly in a village station and the next thrill the punters by storming Lintley Bank with a heavy train."

Early trials were disappointing, with 'Green Dragon' regularly running short of steam.

One of the problems with 'Blazer Logs' is their calorific value compared to that of coal. Martin says: "The manufacturers quote 5.5kWh per kilogram, comparable with 8.39kWh per kilogram for Ffos-y-Fran-supplied soft bituminous coal. Dry wood is reported to work out at 4.5kWh per kilogram which, although it justifies the manufacturer's claims for the superiority of their product over plain logs (a saving of 40%), we are still looking at approximately only two thirds the energy value of Welsh coal."

Another issue is that 'Blazer Logs' are not hydrophobic (i.e.: they can absorb water) and require dry storage. "A rain shower that would just run off a coal dump would turn 'Blazer Logs' into a soggy mess that could be mistaken for porridge. They will not burn in that condition!" says Martin.

However, much perseverance from STR crews established how optimal performance could be obtained. While they're not as thermally efficient as coal, 'Blazer Logs' combine many of the advantages of oil firing with few of the drawbacks. They are relatively clean-burning, and disposing of an engine after a day's turn is easier than when using coal. Perhaps more subjectively, the fireman still needs to shovel a combustible solid into the firebox.

It's not all good news though. 'Blazer Logs' are more expensive than coal. Martin estimates that during a typical day's service, a conventional coal-fired locomotive – even with an inexperienced fireman wielding the shovel – will burn through £115 worth of coal, whereas 'Green Dragon' will consume around £450 of 'Blazer Logs'.

"In other words," says Martin, "it costs around four times as much to diagram 'Green Dragon'. Perhaps as firemen's experience grows, use of the 'Blazer Logs' will become more economical. What could really shift the balance is a big escalation in the cost of coal, which is what many now fear."

A more detailed analysis of the South Tynedale Railway's experiences with 'Blazer Logs' will appear in a future edition of *Steam Railway*.

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> JOHN HIND, CHAIRMAN, ADVANCED STEAM TRACTION TRUST

If ‘Blazer Logs’ prove uneconomical, are there any other fuels we can explore?

One option is biocoal, an experimental new fuel which, on paper at least, has the benefits of options such as ‘Blazer Logs’ and eliminates the shortcomings.

Biocoal is carbon-neutral, combustible solid fuel being developed by the US-based Coalition for Sustainable Rail (CSR) in collaboration with the University of Minnesota’s Natural Resources Research Institute (NRRI). It is designed to have similar properties to coal and is created through torrefaction, a process whereby “raw biomass is heated up in a sealed, oxygen-less environment to between 250-300°C, a process known as partial pyrolysis,” explains the CSR. “Once torrefied, or roasted, the biocoal is densified at a specific temperature and, thanks to the remaining sappy lignin in the wood, requires no binding agent to maintain its form, which can be pellets, briquettes, bricks or any other shape, as requested by the end user.”

In other words, torrefaction artificially accelerates the process by which ancient woodland was naturally condensed and compressed over millions of years until it was transformed into coal.

“When torrefied, the energy density of the material increases to roughly 10,500 BTU/lb [British Thermal Units per pound], it no longer contains the mix of volatiles, it is hydrophobic, it is equally easy to grind as carbon coal and is very easy to transport, and the material only loses about 15% of its calorific value while being 96% thermally efficient to produce.

“What started as wood is transformed into a coal-like biofuel that features none of the heavy metals, sulphur, phosphorus or net carbon emissions of coal. The feed stock is also carbon-neutral, having sequestered carbon as it grew and, so long as the forest stock is sustainably managed, will remain a carbon-neutral fuel source.”

Donald R. Fosnacht PhD at the NRRI says: “There are benefits associated with biomass in comparison to coal, including low sulphur content, no mercury, and low net carbon emissions. The slightly lower energy density, when compared with fossil coal, is offset by the lack of moisture, lower ash content and the high radiant heat output of the fuel.”

Biocoal appears to be more thermally efficient than fuels like ‘Blazer Logs’, more resistant to water (and therefore easier to store and handle), and better for the environment than coal while still sharing most of its positive properties.

- To find out more about biocoal, visit *www.csrail.org/torrefied-biomass*

This Java-based Orenstein & Koppel 0-8-0T, built to burn bagasse (sugar cane waste), demonstrates the storage and spark-emitting problems of burning wood-based material. Note the extension rails fitted to the auxiliary tender to accommodate the fuel. COLIN GARRATT/ALAMY

It sounds great in theory, but how does it fare in practice?

In summer 2016 and autumn 2017, the CSR conducted a number of biocoal tests at the Milwaukee County Zoo’s 15in gauge railway.

CSR President Davidson Ward says: “The number one conclusion from those tests is that this fuel can serve as a viable alternative for coal. When of proper size, densification, and with an appropriate binder, the torrefied biomass fuel made comparable heat to coal, but did so with minimal ash and smoke.

“Our initial trials at the zoo generated proper heat, but the pellet sizing and densification we used emitted more sparks than we found acceptable. The third trial, using fuel made with a more advanced densification system, addressed that issue and served as a proof of concept.”

The next stage is to scale up its tests by evaluating biocoal on a standard gauge ‘Mogul’ at the Everett Railroad, Pennsylvania, in spring this year.

Davidson adds: “Our objective is to advance commercialisation of biocoal to the point that regional plants can be established to economically serve the various operators before the price of coal increases to the point of operators having to sideline their locomotives.”

It all sounds too good to be true...

Before we declare biocoal to be our salvation, some outsiders are more incredulous about its viability. Howard Johnson says: “This is basically roasted sawdust which is then compressed into briquettes, which may or may not work; I suspect it won’t! Most wood briquettes I have seen eventually fall back into sawdust.

“A current price indication is over $280 (£210) per tonne, I believe. This is for a product that only produces a net heat of approximately 9,000 BTUs, which would struggle to cook the driver’s breakfast, never mind raise steam and sustain efficient running.”

Keighley & Worth Valley Railway locomotive department spokesman Ralph Ingham is less critical, though he’s still sceptical: “I was taught that [a tonne of] good, hard coal could provide around 12,000 BTUs and Welsh coal around 15,000. The [CSR’s] upper expectations are, therefore, at the bottom end of what we might feel to be useful. Beggars can’t be choosers however, and biocoal might be something that less-testing lines could get by with, or might work for engines with wide fireboxes.

“One cannot fault their desire to find a solution, but even if it did sufficiently meet our needs and price sensitivities – which I doubt – consider the size of the plant required to supply even a proportion of the UK market, let alone that in the US.”

The latter point is backed up by Donald R. Fosnacht: “The NRRI operates its reactor on a research basis and for batches, depending upon which research collaborator requests fuel. Were the reactor to be operated on a continuous basis, we could produce approximately 1,000 tonnes of torrefied product per year.” On that basis, the UK would need nearly 40 similar plants to meet the preservation sector’s annual demand, assuming that a tonne of biocoal is equivalent to a tonne of coal.

Some have also questioned biocoal’s hydrophobic qualities, but Donald says: “Our researchers have identified certain binders that impart significant hydrophobicity to the product and would allow it to be stored like coal outside. At present, the use of a simple roof over the torrefied fuel, without climate control,

Milwaukee County Zoo 'Pacific' No. 1924 hauls one of the biocoal test trains on November 6 2017.
→ INSET: **The 100% torrefied biomass used in the November 2017 tests.**
BOTH: COALITION FOR SUSTAINABLE RAIL

will keep the torrefied biomass protected and the hydrophobicity of current stock will be sufficient to allow it to be stored with minimal infrastructure. In terms of long-term storage, we have had no issues with dry/simply covered storage."

Has biocoal been trialled anywhere else?
Yes. In 2012, the Advanced Steam Traction Trust – the team behind the aborted '5AT' new-build project, and which has fitted an improved Lempor exhaust into the Keighley & Worth Valley Railway's 'S160' No. 5820 'Big Jim' to improve draughting – carried out a series of tests at the 10¼in gauge Stapleford Miniature and Wells & Walsingham railways.

ASTT Chairman John Hind says: "For the trials at Stapleford in April, we tried compressed wood chips and torrefied wood, which were soon discounted because of smoke, spark throwing and inability to maintain steam. Biocoal was first tried in June and showed the most promise, though the product available in 2012, while it came close to the energy content of coal, was less dense, dusty and could break up on handling.

"In July 2012, the trials moved to the Wells & Walsingham Light Railway, which has substantially larger engines than Stapleford, and an eight-mile round trip on a line with heavy gradients. The biocoal used for this trial was an improved version of the previous grade with less dust and fines.

"The earlier trials of biocoal at Stapleford gave concerns about fast burning and spark and smoke emissions, but the trial with a larger engine and firebox confirmed that the heat output was satisfactory.

"The major concern was the excessively fast burn rate under high draught conditions which, combined with the lower bulk density of the product, made it virtually impossible to build a workable firebed without constant firing. The consumption of biocoal was around four to five times the volume of Welsh steam coal.

"Under light draught, biocoal performed quite well – it could be fired intermittently and maintain steam pressure, but as soon as a higher draught was required, holes appeared immediately in the firebed. Trying a thick bed required constant firing and even then, the bottom of the fire was burning away so quickly that it was not possible to build it to a suitable depth.

"The view at the time was that if the biocoal could be produced with greater compression and hence with greater density and in larger sizes, it would decrease the burn rate and reduce smoke and spark emissions."

In summary, John believes: "Biocoal and its use in locomotives is still in the development phase. It may be a viable successor to coal, provided it can come close to the characteristics of coal and can be produced in bulk, to make it a commercially available product, at an economic price."

In terms of cost, Donald R. Fosnacht says: "The fuel manufactured at our facility is done on a per-batch basis and as a demonstration, and therefore is more expensive than if it were manufactured at a larger scale. The two biggest factors driving fuel costs are the costs of the input biomass and the cost of converting that biomass to biocoal. Our estimates of commercial torrefied biomass production place it slightly higher than high-quality US bituminous coal, depending upon the input biomass cost."

Are any of these alternative fuels a viable substitute for coal?
As things stand today, no. All of the feasible alternative fuels outlined above have problems that, while not insurmountable, make them impractical.

Ovoids should be discounted outright, and oil firing, though outwardly attractive, is too expensive and environmentally problematic to consider seriously. Processed natural wood fuel products such as the 'Blazer Logs' used at South Tynedale have potential, but they're designed for domestic stoves rather than locomotive grates, and there are arguably too many unknown factors standing in the way of their long-term viability.

But what about biocoal? It has the potential to be the perfect substitute for coal, providing its development continues on an upwards trajectory and that its funding is sustained. It's still early days for this experimental fuel however, and it will likely be years before it becomes both more widely available and more affordable.

The elephant in the room is that none of these alternative fuels is a match for good quality, low-sulphur coal, but as Ralph Ingham says, if good-quality coal becomes unavailable or uneconomical, then we might have to take what we can get: "beggars can't be choosers." SR